Remote Sensing of Temperature and Salinity Microstructure in Rivers and Estuaries Using Broadband Acoustic Scattering Techniques

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LONG-TERM GOALS

To measure and understand high-frequency broadband acoustic scattering in rivers and estuaries characterized by strong temperature and salinity gradients and intermittent and often high plankton and particle concentrations and dissipation rates of turbulent kinetic energy. To use these measurements and understanding to develop a remote sensing tool for quantifying the structure of stratified turbulence.

OBJECTIVES

The primary objective of the proposed research is to measure high-frequency broadband acoustic backscattering in highly stratified, energetic environments (such as rivers and estuaries), where there is significant salinity stratification. Testing the validity of existing microstructure scattering models (Lavery et al., 2007) and quantifying the contribution to scattering from salinity versus temperature stratification over a broad frequency range are secondary objectives of this work.

To accomplish the stated objectives, high-frequency broadband acoustic backscattering measurements will be performed in the Connecticut River in November 2008 and March 2009. Two broadband acoustic scattering systems will be deployed: 1) a broadband system spanning 150 kHz – 600 kHz, developed by Edgetech, will be pole mounted at the surface looking down, and 2) a broadband system spanning 150 kHz -1250 kHz, with some gaps, currently under development at WHOI, will be deployed from Rocky Geyer's (WHOI) Mobile Array for Sensing Turbulence (MAST). The contribution to scattering from biological organisms will be quantified by Scott

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14. ABSTRACT
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Gallager (WHOI) through use of an optical recording device (the video plankton recorder or VPR) also mounted on the MAST. For these measurements to allow the determination of dominant scattering processes and result in enhanced understanding, and ultimately in the development of acoustic techniques for the remote-sensing and quantification of stratified turbulence, it is critical to integrate the acoustic, turbulence, and optical instrumentation on a measurement platform, such as the MAST, which allows almost coincident measurements to be performed.

APPROACH

The approach taken here to understanding acoustic scattering in highly stratified, energetic environments involves the combination of field measurements in which as many sources of scattering as possible are characterized, and the interpretation of the data within the framework of existing physics-based acoustic scattering models.

The data analysis involves capitalizing on the broadband nature of the transmitted signals and using pulse compression techniques (Chu and Stanton, 1998) to both increase the signal to noise ratio and the spatial resolution of the measurements. It has been possible to obtain almost cm scale resolution in the direction of acoustic propagation using these techniques, a significant improvement over traditional single-frequency echosounder observations of water-column scattering. Additional information is obtained by further capitalizing on the broadband nature of the acoustic signals by using the spectral content of the scattering to determine if the scattering is consistent with scattering from small-scale physical processes or biology. In regions in which the scattering is determined to be dominated by turbulent microstructure, turbulence parameters, such as the dissipation rate of turbulent kinetic energy, can be inferred. Direct measurements of microstructure and biology are important for allowing comparisons of acoustic measurements to physics-based model simulations.

WORK COMPLETED

The primary effort to date has been in the preparation and calibration of instruments for the field measurements to be conducted in the Connecticut River from 16 November 2008 – 20 November 2008. The Connecticut Rives (Fig. 1) was chosen as a desirable location for the field work as strong acoustic backscattering (measured with an ADCP) has been seen previously associated with an intense shear instability, with classic Kelvin-Helmholtz appearance, formed when fresh surface water ebbs over a relatively stationary saltier lower layer. The experiments will be conducted over a 5-day period and will involve along river transects sampling both flood and ebb, as well as anchor station at three select locations (Fig. 1).

The primary platform for the measurements is the Measurements Array for Sensing Turbulence (MAST) which will be deployed from the R/V Tioga (WHOI's 60' coastal research vessel). The MAST is outfitted with acoustic Doppler velocimeters (ADVs), micro-conductivity sensors, and supporting measurements of platform motion. The MAST provides a unique means of measuring turbulent velocities and scalar fluxes in estuarine and fluvial environment as continuous measurements at multiple vertical locations through the water column can be obtained, producing continuous temporal resolution of the turbulent processes. A broadband acoustic backscattering system, currently under development at WHOI, and optical imaging instrumentation will also be added to the MAST providing co-incident measurements. In addition to the MAST, continuous CTD profiles will be performed and a profiling microstructure instrument will be deployed from the R/V

Mytilus (WHOI's 24' coastal research vessel), and an ADCP and surface-mounted broadband acoustic system (described above) will be pole mounted from the R/V Tioga.

RESULTS

This project is its infancy. The primary results to date involve development of instruments and preparation for a field experiment. A 3-channel high-frequency broadband acoustic backscattering system is under development at WHOI, spanning the frequency range from 150 kHz to 1250 kHz, with slight gaps: the low-frequency channel spans 150-270 kHz, the mid-frequency channel spans 450-650 kHz, and the high-frequency channel spans 750-1250 kHz. The low- and mid- frequency channels use Airmar transducers (low: 9.5 degree full beamwidth at center frequency, mid: 3 degree full beamwidth at center frequency) while the high-frequency channels uses a Panametrics NDT transducer (3.4 degree full beamwidth at center frequency). The system, to be deployed on the MAST, is designed to be autonomous and compact, providing deployment flexibility and low noise. The system components have been developed (e.g. primary electronics components, underwater housing, matching transformers for the transducers), however the system still needs to be assembled, tested, and calibrated. Mounting brackets have been constructed. The Edgetech broadband acoustic scattering system has been deployed in two different configurations (profiled and bottom mounted) in previous experiments, including SW06, RACE08, and currently for SPACE08. Mounting modifications have been made to deploy this system from a pole mount on the RV Tioga.

IMPACT/APPLICATIONS

In order to use high-frequency acoustic scattering techniques in a quantitative fashion for remote sensing applications, it is important to understand the circumstance under which different processes contribute to the scattering. Only recently has it become more generally accepted that microstructure can contribute significantly to scattering, under certain circumstances. The goal of the measurements to be performed is to provide additional evidence that small-scale physical process can be significant contributors to volume scattering in regions of stratified turbulence, and will provide new insight into the importance of scattering from salinity versus temperature microstructure in rivers and estuaries. Measuring scattering over a wide range of frequencies is key to enhancing our understanding. The ultimate research goal is to develop broadband acoustic backscattering techniques for remote characterization of stratified turbulence, representing a valuable tool for physical oceanographers, particularly in river and estuarine environments where continuous, high-resolution measurements as a function of depth are challenging.

RELATED PROJECTS

"High-Frequency Broadband Acoustic Scattering from Temperature and Salinity Microstructure: From Non-Linear Internal Waves to Estuarine Plumes," Lavery, A.C. Funded by ONR Ocean Acoustics.

"Development of an autonomous broadband acoustic scattering system for remote characterization of zooplankton," Lavery, A.C., Terray, E., and Sutor, M. Funded by ONR Marine Mammals and Biology.

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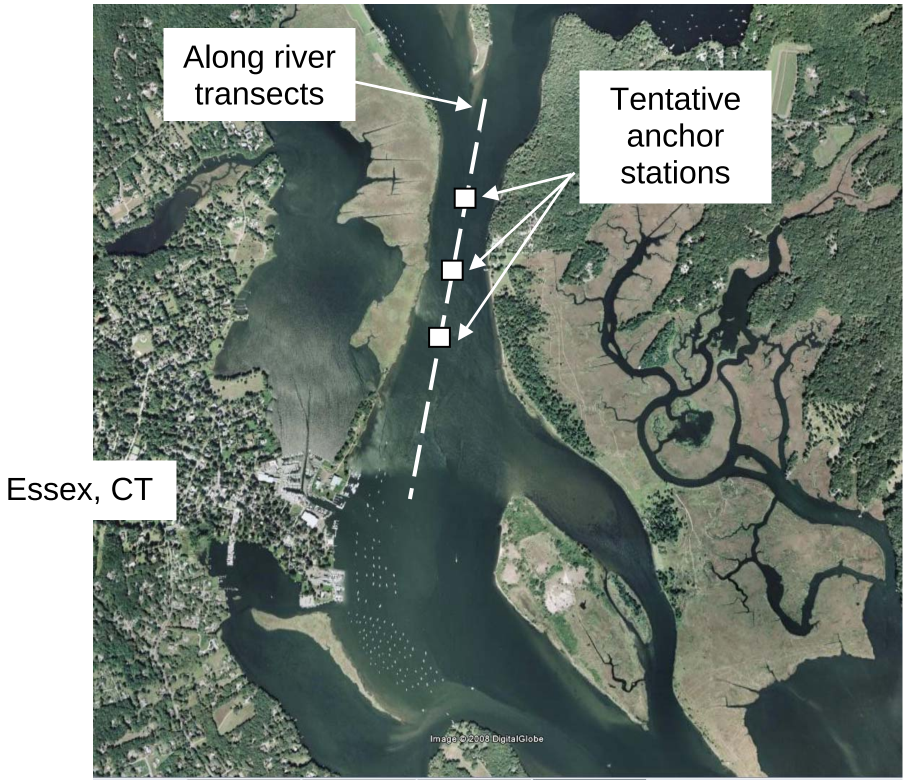

Figure 1: The Connecticut River by Essex, CT, location of the upcoming field work in November, 2008, aimed at measuring broadband acoustic backscattering from stratified turbulence.